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A LIFE-CYCLE COST MODEL FOR AN ELECTRONIC MAINTENANCE TRAINER.(U)

AUG 82 L J MARK, D KRIBS, J W SCHULER N66001-80-C-0090

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NPRDC SR 82-33 AUGUST 1982

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NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIFORNIA

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NPRDC Special Report 82-33 August 1982

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NPRDC SR 82-33

2. GOVT ACCESSION NO.
AD A118435

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
LIFE-CYCLE COST MODEL FOR AN ELECTRONIC MAINTENANCE TRAINER

5. TYPE OF REPORT & PERIOD COVERED
Jan 1980-March 1981

6. PERFORMING ORG. REPORT NUMBER
~~14-81-10~~

7. AUTHOR(s)
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8. CONTRACT OR GRANT NUMBER(s)
N66001-80-C-0090

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Instructional Science and Development, Inc
San Diego, California 92107

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Z0789-PN

11. CONTROLLING OFFICE NAME AND ADDRESS
Navy Personnel Research and Development Center
San Diego, California 92152

12. REPORT DATE
August 1982

13. NUMBER OF PAGES
36

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Life-cycle costs
Cost estimation
Maintenance costs
Work breakdown structure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research was conducted in support of the Class "A" electronic equipment maintenance training system (EEMT) program. This report describes the development of the EEMT life-cycle cost model. Cost data for EEMT planning, programming, and budgeting are provided through cost estimation and work breakdown structures.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

This research and development was conducted under contract by Instructional Science and Development (ISD), Inc., in support of Navy Decision Coordinating Paper Z0789-PN, Class "A" Electronic Equipment Maintenance Training (EEMT) System. It was sponsored by the Chief of Naval Operations (OP-01).

The EEMT project has been divided into four phases: concept formulation, system definition, prototype development, and system test and evaluation. This report is the fourth in a series. The first three NPRDC reports (TN 79-3, TR 81-11, and SR 81-19) described the concept formulation and system definition phases. This report describes the development of an EEMT life cycle cost model. Data provided herein are intended for use by those concerned with planning, programming, and budgeting for EEMT production (Device 11B106) and similar maintenance training systems.

The contracting officer's technical representative was Mr. T. D. Pope.

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SUMMARY

Problem

To reduce its reliance on the use of operational equipment in maintenance training in Class "A" schools, the Navy initiated a research, development, test, and evaluation program for a generic electronic equipment maintenance training (EEMT) system. Operational Requirement PN50 calls for a long-range reduction of at least 50 percent over the life-cycle costs (LCC) of conventional hardware in electronics maintenance training.

As EEMT program milestones have been accomplished, both the system configuration and the utilization plans have become more definite. To provide updated data to support Navy planning, programming, and budgeting decisions, it was necessary to (1) determine the impact of changes in EEMT system configuration and utilization plans, (2) revise a previously developed life-cycle cost model (LCCM) to reflect these changes, and (3) provide a set of updated LCC estimates.

Objective

The objective of the research was to develop a revised LCCM and then to use it to make new LCC estimates. The new LCC estimates were, in turn, to be used as a basis for determining whether the goals of Operational Requirement PN50 could be accomplished through the use of EEMT.

Approach

The framework for the LCCM was a work breakdown structure matrix reflecting the LCCs associated with two alternative approaches to maintenance training: (1) the use of conventional hardware and (2) the use of the EEMT. The following steps were taken in developing LCC estimates for comparison:

1. The curricula of two class "A" technical schools, Electronics Technician (ET) and Electronics Warfare (EW), were analyzed to identify those topics that could be taught using EEMT units. The number of EEMT units needed to teach these topics was estimated.

2. Replacements of conventional hardware in the ET and EW "A" school inventories were projected over the life cycle.

3. Operational support costs for the projected equipment acquisitions were derived.

4. The LCCs for the EEMT units were estimated for both schools.

5. Costs for conventional curriculum development and maintenance over the life cycle were computed.

6. Costs for developing and maintaining the EEMT curriculum were derived, based on a model that defined the personnel requirements and instructional materials development process.

Results

The results of the comparative life-cycle cost analysis indicate that the LCC of the hardware used in maintenance training in the ET and EW schools can be reduced by 50 percent by implementing EEMT. The total life cycle costs for operational equipment in the two schools were estimated at $31,743,425, compared to $13,794,050 for EEMT. This represents a 57 percent reduction over the projected 12-year life cycle.

Conclusions

It appears that at least a 50 percent life-cycle cost reduction can be achieved with reduced reliance on operational equipment and increased hands-on training experience through the implementation of EEMT. Although EEMT will not replace all operational equipment in the schools, substantial reductions are reasonable if training effectiveness is found to be the same or better in the EEMT test and evaluation.

Recommendations

1. To provide historical cost data, the cost of developing the EEMT instructional modules to be used during device test and evaluation (DT&E) should be recorded as they accrue. Breaking down these costs by development task and personnel type will permit realistic manpower planning and cost estimates for future curriculum development and maintenance efforts.

2. The LCCM should be updated during DT&E to provide more reliable estimates of EEMT LCC to determine whether the EEMT should be used in other "A" schools.

CONTENTS

INTRODUCTION

Problem

To reduce its reliance on the use of operational equipment in maintenance training in Class "A" schools, the Navy initiated a research, development, test, and evaluation (RDT&E) program for a generic electronic equipment maintenance training (EEMT) system. Operational Requirement PN50[1] calls for a long-range reduction of at least 50 percent over the life-cycle costs (LCC) (acquisition, operation, and maintenance) of conventional hardware in electronics maintenance training.

As EEMT program milestones have been accomplished, both the system configuration and the utilization plans have become more definite. To provide updated data to support Navy planning, programming, and budgeting decisions, it was necessary to (1) determine the impact of changes in EEMT system configuration and utilization plans, (2) revise a previously developed life-cycle cost model (LCCM) to reflect these changes, and (3) provide a set of updated life-cycle cost estimates.

Objective

The objective of the research was to develop a revised LCCM, and then to use it to make new LCC estimates. The new estimates were, in turn, to be used as a basis for determining whether the goals of Operational Requirement PN50 could be accomplished through the use of EEMT.

Background

Navy Class "A" schools play a central role in supplying trained personnel to operate and maintain the fleet's electronic equipment. The traditional Navy electronics training system emphasizes the use of operational equipment in maintenance training in Class "A" and Class "C" schools. However, because of the rapid advances in engineering technology, operational equipment quickly becomes obsolete. Because of high replacement costs, the schools are seldom able to procure up-to-date operational equipment in large enough quantities to meet their training requirements. Additionally, when operational equipment is used as an instructional medium, it can be dangerous, inflexible, and, sometimes, invalid.

In an effort to reduce its inventory of operational equipment used for maintenance training, the Navy has initiated an RDT&E program for a generic EEMT system. The program consists of four phases: (1) planning, (2) system definition, (3) system design and production, and (4) implementation and evaluation. Each phase is dependent upon the outcome of the preceding one. The program is currently in Phase 3, system design and production. During this phase, enough prototype EEMT systems will be produced to permit an operational assessment of their performance in two target Class "A" schools--Electronics Technician (ET) and Electronics Warfare (EW). During the next phase, implementation and evaluation, its training and cost effectiveness will be assessed to determine whether production of the EEMT system and its use in other Class "A" schools is warranted.

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[1] Operational requirement of Class "A" electronic equipment maintenance training system (OR-PN50). Washington, DC: Chief of Naval Operations, 26 July 1976.

With the growing demands on Navy manpower resources, increasing training requirements for fleet operational readiness, and limitations on Navy training budgets, the development and implementation of the kinds of advanced training technology represented by EEMT should not be undertaken without considering the variables that influence costs and benefits. A systematic approach is needed to determine the effectiveness and cost of the new technology over its projected life cycle. One such approach, economic analysis, has been defined by the Department of Defense[2] as:

> A conceptual framework for systematically investigating problems of choice. An economic analysis postulates alternative means of satisfying an objective and investigates the costs and benefits of each of these alternatives.

An economic analysis was conducted during the planning phase of the EEMT program. Its purposes were (1) to develop an LCCM, including benefits statements, to serve as a program management decision-making tool, (2) to develop an initial set of LCC estimates and benefits statements to test the utility of the model, and (3) to provide the baseline data needed to support planning, programming, and budgeting of the EEMT program.

One of the goals of the research described herein was to develop revised LCC estimates to be used as a basis for determining whether or not the EEMT program's goal of reducing long-range costs to 50 percent of the expected cost of using operational equipment for training is feasible.

APPROACH

The approach consisted of first developing a revised LCCM and then using it to estimate the LCCs associated with two alternative approaches to maintenance training: (1) the use of operational equipment for maintenance training and (2) the use of EEMT with a reduced inventory of operational equipment for maintenance training.

The approach consisted of five tasks.

1. Analysis of existing EEMT documentation.

2. Collection and analysis of data.

3. Revision of the LCCM.

4. Development of LCC estimates. (The appendix gives additional details on the development of the LCC estimates.)

5. Comparisons of life-cycle costs.

Analysis of Existing Data

Existing documentation was analyzed to identify the changes that had been made to the initial system configuration and utilization plans. The EEMT specifications were

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[2]Economic analysis handbook (2nd ed.). Washington, DC: Defense Economics Analysis Council, Handbook Committee, Department of Defense, Undated.

reviewed to identify system components, changes in hardware and software capabilities, and support requirements. Documents pertaining to EEMT utilization plans were examined for relevance. The three major components of the training pipeline--equipment, students, and curriculum--were studied for changes. The three objectives for economic analysis and the performance goals/benefits taken from OR-PN50--development of an LCCM, development of LCC estimates, and provision of baseline planning data--were reviewed. The draft of the Device Test and Evaluation Master Plan for EEMT (Pine, Daniels, & Malec, 1981) was reviewed to identify the critical developmental and operational issues to be assessed during the implementation and evaluation phase. The issues were analyzed for potential impact on the EEMT system configuration and utilization plans during the system design and production phase.

Collection and Analysis of Data

There were four types of data to be collected and analyzed within the LCCM:

1. The costs associated with Alternative 1, the use of operational equipment for laboratory maintenance training in the ET and EW "A" schools.

2. The costs associated with Alternative 2, the implementation of EEMT.

3. The curriculum development and maintenance costs associated with each alternative.

4. The cost benefits associated with each alternative.

Several data collection techniques and sources of data were used to determine changes in EEMT system configuration and utilization plans. During visits to the ET and EW "A" schools, classrooms and laboratories were toured and interviews were conducted with management and administrative personnel, training equipment maintenance support personnel, instructors, and Instructional Program Development (IPD) Detachment personnel. Topics of discussion included the impact of introducing EEMT into the training pipeline, potential applications, current and projected equipment inventories, training equipment support requirements and billets, current and projected status of curriculum development and maintenance efforts, and student throughputs.

The training program coordinators for the ET and EW "A" schools were interviewed. Topics of discussion included plans for operational equipment acquisitions, changes in the curriculum and pipeline flow, potential EEMT applications, and student throughput projections. The critical developmental and operational issues outlined in the draft RDT&E plan were discussed with members of the Training Analysis and Evaluation Group (TAEG).

Telephone interviews were conducted with personnel from the Chief of Naval Education and Training (CNET), the Naval Electronics Systems Command (NAVELEX-SYSCOM), and the Naval Sea Systems Command (NAVSEASYSCOM). Topics of discussion included projections for operational equipment support and the current status of Navy Training Plans for the ET and EW ratings.

Meetings were held to develop the prototype EEMT system to be evaluated during the implementation and evaluation phase. Topics of discussion included EEMT system configuration requirements, potential production model acquisition and support costs, and curriculum development cost estimates.

Revision of the Life Cycle Cost Model

The LCCM was revised on the basis of the review of EEMT documentation and the analysis of data collected during the interviews. The following sections describe the modeling process, the framework for the LCCM, the cost estimating techniques, and the basis for comparing the costs of the two alternatives.

Modeling Process Used to Develop Initial LCCM

A work breakdown structure (WBS) format for the model was selected to meet the objectives of the economic analysis. The WBS format offers the following advantages cited by Grosson and Rakow (1974):

> The WBS matrix can be used as the basis for a cost-tradeoff model to compare various alternatives on a life-cycle cost basis. By using constant year dollars for each element in the matrix, a present worth comparison of alternatives is readily obtained.
>
> Total program cost is not always the only criteria for evaluating alternatives. The WBS cost matrix can be modified by application of escalation factors and compared on a fiscal year basis to ascertain whether the most economical alternative is also politically palatable.
>
> The WBS provides the program manager with a detailed low-level breakout of all cost elements. Such detail provides strong defense of the total program budget and most accurate analysis of the impact of budget reductions. The specific elements affected and the time phasing are readily apparent when the WBS is used in the budget process.

A WBS cost model used by training program managers in the Naval Material Command (NAVMAT) served as the basis for developing the LCCM. The NAVMAT WBS, developed in accordance with MIL-STD-881, was keyed to certain integrated logistic support (ILS) phases prescribed by SECNAV Instruction 5000.1.[3] Therefore, the following features were included in the model:

1. Elements are distinct so each can be monitored as a separate entity.

2. Separation by appropriation is easily facilitated.

3. Separation by program participant is facilitated (i.e., contractor, civilian, or military).

Initially, the NAVMAT WBS elements were analyzed to identify those cost components that were relevant to both alternatives. The cost variables in the training effectiveness and cost effectiveness prediction (TECEP) technique developed by TAEG (Braby, Henry, Parish, & Swope, 1975) were also analyzed to identify any cost components

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[3] System Acquisition in the Department of the Navy (SECNAV Instruction 5000.1). Washington DC: Secretary of the Navy.

to be added to the model. The final version of the LCCM was based on training pipeline characteristics that were determined to be relevant to the objectives of the economic analysis. The benefit statements included in the LCCM were the performance goals stated in OR-PN50 (see note 1). These performance goals were translated into productivity measures and tied to WBS cost elements so that quantitative as well as qualitative statements on training effectiveness could be made.

Development of the Revised LCCM

For the revised LCCM, two matrix cost models were analyzed to ensure that all of the relevant cost elements for the two alternatives were included in the WBS model. One of the models was developed to reflect the types of costs by function and by sources for maintenance simulators. The other model was developed to provide a set of standard tools to evaluate the cost effectiveness of a computer-based training system (Seidel & Wagner, 1977). Both of these models emphasize the three phases of a training system's life cycle; that is, development, procurement, and operation and maintenance. However, the cost elements associated with development were assumed to be part of the RDT&E costs for a prototype training system, whether it used prime equipment or a training device/simulator like EEMT. Therefore, only the cost elements pertaining to procurement and operation and maintenance were considered in revising the LCCM.

Several other recent documents were reviewed for relevance in updating the LCCM. A draft document[4] specifying support requirements for the development and acquisition of Navy training systems was reviewed to ensure that the appropriate integrated logistic support elements were included in the model. The draft user manual[5] for the software specified for data base development for the EEMT 2D unit was analyzed to determine the impact on curriculum development and maintenance cost elements in the model.

Framework for the LCCM

The framework for the LCCM is provided in Table 1. All elements apply to both alternatives. Element 1.0 identifies the investment costs associated with procurement of training equipment. These cost components assume that design, development, and operational testing of the prototype have been successfully completed and that production model training systems are available. Element 2.0 represents the nonrecurring and recurring logistic support costs required to implement and support the training device over its life cycle. Element 3.0 identifies the recurring operation and maintenance costs associated with the training system over its life cycle.

Elements 4.0 and 5.0 of Table 1 reflect the cost of developing and maintaining curricula. Subelements 1, 2, and 3 of Element 4 were based on the first three phases in the instructional systems development[6] (ISD) procedures--analysis, design, and development. The last two phases of the ISD procedure--implementation and control--were included in Element 5.0.

An additional subelement, replacement training, not broken out separately, was included in Elements 4.0 and 5.0 to cover costs for providing instructor and maintenance training as personnel change billets during the system life cycle.

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[4]Pope, T. D. A Supportability Guide for Training Devices. Unpublished paper, 1979.

[5]Prepared by Behavioral Technology Laboratories, 1980.

[6]Interservice procedures for instructional systems development (NAVEDTRA 106A). Pensacola, FL: Chief of Naval Education and Training, 1975.

Table 1

Elements and Subelements of the Work Breakdown Structure (WBS)

Elements and Subelements of the WBS	Navy Appropriation Category
1.0 Training System Acquisition	Operational Procurement
01 Training Equipment	
02 Support documentation/Equipment Manuals	
001 Logistics Plans	
002 Provisioning Documentation	
003 Maintainability Program	
004 Technical Publications	
03 Test Equipment	
04 Training Devices	
2.0 Training System Logistic Support	Operational Procurement
01 Initial Spares/Maintenance Kit	
02 Installation and Test	
03 On-Site Maintenance Training/Instructor Training	
04 Technical Services/Training Advisory Services	
05 Hardware/Software Modifications	
001 Hardware Modifications	
002 Software Maintenance	
3.0 Training System Operational Support	Operation & Maintenance
01 Repair and Return Services/Replenishment Spares	
02 Calibration	
03 Overhaul	
04 Organizational Maintenance	
001 Contractor Field Services	
002 On-site Military Support	
4.0 Curriculum Development	Operation & Maintenance
01 Analysis	
02 Design	
03 Development	
5.0 Curriculum Maintenance	Operation & Maintenance
6.0 Students	Military Personnel

Although not explicitly stated, these elements reflect personnel costs for IPD detachment staff, subject-matter experts, instructors, and administrative support staff, as well as media methods and materials costs. These personnel costs were not assumed to be complete or comprehensive; they represent the differences in personnel requirements needed to develop and maintain curriculum for the training systems under consideration.

It was assumed that the introduction of EEMT would not affect the size of the instructional or administrative staffs. Although there may be increases or decreases in the number of personnel during the system life cycle, they will be due to other factors, such as personnel availability. The EEMT might alter the time allocated to specific functions, but it was beyond the scope of the study to determine the effects of those changes on personnel requirements.

The cost of managing new training systems was assumed to be a relatively fixed cost embedded within the affected training organizations. Therefore, only those program management costs that were unique to the training systems under consideration were included in the model. Facilities costs were also ignored, since the introduction of EEMT would have negligible effects on facilities.

Development of LCC Estimates

Industrial engineering and "cost factors" methods were used to derive the LCC estimates. The industrial engineering method, which was used to develop the LCCM, is based upon an extensive knowledge of system characteristics. That is, the system under analysis is broken down into elements or components, costs are estimated for each component, and the costs then are aggregated into total system costs. This method provides both a detailed picture of the costs of technical trade-offs and precise statements of the assumptions used to determine the cost of each component.

Cost factors, which provide the most common method of deriving cost estimates for training systems, were used extensively in developing the life-cycle cost estimates for both alternatives. As defined by Swope (1976), "a cost factor is a single multiplier such as a cost per unit of a resource, or a ratio relating the cost of a portion of a system to the cost of another controlling portion of the system." When used as multipliers, cost factors permit the analyst to identify resource requirements and their costs. When used as a ratio, cost factors provide crude estimates that serve as a means of focusing on relevant ranges for planning.

Comparing the LCCs of Both Alternatives

The LCCs of Alternatives 1 and 2 were compared to determine whether or not implementation of EEMT could satisfy the objective calling for a 50 percent reduction in equipment costs. The comparison was based on identification of potential EEMT applications in the ET and EW "A" school curricula. Detailed analyses of each school's training pipeline resulted in tentative specifications of the topic areas and classroom/laboratory hours that could be accomplished on EEMT. The percentage of EEMT hours within the total number of curriculum hours for each school was then used to derive cost estimates for both alternatives.

To facilitate comparisons, all estimates were presented in FY 1980 constant dollars. Escalation rates were applied to cost estimates in current year (then) dollars based on the average inflation rates for the time periods under consideration. The period of comparison for the two alternatives was a 12-year life cycle from FY 83, the projected date for installation of production EEMT units, through FY 94.

RESULTS

LCC Estimates

Table 2 summarizes the major cost elements for the two alternatives over the projected life cycle. Alternative 1 represents cost estimates for the status quo and Alternative 2 represents cost estimates for EEMT.

As described earlier, only those portions of ET and EW training that could be accomplished by EEMT were included in the LCCM; hence, only the costs directly associated with the implementation of EEMT in the ET and EW "A" schools were considered in the comparative analysis. The total cost of ET and EW maintenance training was not estimated.

The total LCC for use of conventional hardware in ET and EW maintenance training was estimated at $31,743,425, while the total LCC for EEMT was estimated at $13,974,050. This represents a 57 percent reduction in the costs of acquisition, operation, and maintenance of current training methods over the projected 12-year life cycle. Each cost element comparison is described briefly in the following paragraphs.

1. Training system acquisition. For Element 1, the cost estimates for using EEMT exceeded those for using operational equipment. The EEMT estimates represent the nonrecurring costs to acquire a total of 248 2D units, 85 3D units, and 16 instructor consoles to implement 49.2 percent of the curriculum in both schools. The estimates for using operational equipment represent the investment costs associated with introducing new prime equipment and training devices. These estimates were based on training requirements for the AN/WSC-3 radio set, AN/SPS-67 radar set, and AN/SLQ-32 countermeasures system during the projected life cycle. They assume that new equipment and/or training devices would have to be procured in sufficient quantities to meet the requirements. If additional training requirements are identified over the life cycle, these estimates could be significantly higher. However, if EEMT is an integral part of the ET and EW "A" school pipelines, the projected acquisitions to meet the training requirements could be reduced in quantity or replaced by EEMT.

2. Training system logistic support. For Element 2, the cost estimates for using operational equipment exceeded those for using EEMT.

3. Training system operational support. For Element 3, the cost estimates for using operational equipment greatly exceeded those for using EEMT. As expected, both the nonrecurring and recurring support costs are significantly higher for operational equipment than for computer-based training devices like EEMT. The major components are the recurring operation and maintenance costs associated with the use of prime equipment for maintenance training.

Table 2

Comparative Life Cycle Cost Analysis

WBS Element		Cost: Operational Equipment (Alternative 1)	Cost: EEMT (Alternative 2)
1.0	Training System Acquisition		
	01 Training Equipment	$ 1,640,000	$7,282,695
	02 Technical Documentation	2,473,860	0
	03 Test Equipment	0	0
	Total Acquisition Cost	4,113,860[a]	7,282,695[b]
2.0	Training System Logistic Support		
	01 Installation and Test	470,000	13,845
	02 Initial Spares	275,000	196,156
	03 Tools & Test Equipment	0	76,997
	04 Tech Services/Training Advisory Services	7,000	40,000
	05 Maintenance/Instructor Training	0	11,540
	06 Hardware Modification	2,500,000	923,973
	07 Software Updates/Maintenance	2,500,000	270,000
	Total Logistic Cost	5,752,000[c]	1,532,511[c]
3.0	Training System Operational Support		
	01 Repair and Return Services/ Replenishment Services	5,662,751	692,982
	02 Organizational Maintenance	8,922,916	1,634,800
	03 Overhaul	1,416,960	0
	04 Calibration	2,429,880	0
	Total Operational Cost	18,432,507[c]	2,327,782[c]
4.0	Curriculum Development	91,490[c]	478,022[c]
5.0	Curriculum Maintenance	3,353,568[c]	2,173,040[c]
	Total Cost of all WBS Elements	$31,743,425	$13,974,050

[a]Level of confidence Class A. The levels of confidence are explained at the end of the results section, p. 10.

[b]Level of confidence Class B.

[c]Level of confidence Class C/D.

4. Curriculum development. For Element 4, as for Element 1, the estimated cost of using EEMT exceeded the estimated cost of using operational equipment.

5. Curriculum maintenance. For Element 5, the estimated cost of using operational equipment exceeded the estimated cost of using EEMT.

The computer-based capabilities of EEMT minimize the effort required to revise curricula since only minor changes to existing data bases are required and instruction common to both schools needs to be updated only once. The on-line student functions also reduce the requirements for consumables and for reproduction of training materials.

Levels of Confidence in the Estimates

Levels of confidence were assigned to the LCC estimates to provide Navy decision makers with a statement of their accuracy and reliability. The levels were based on cost estimate categories taken from OPNAV's Cost Analysis.[7] These categories were:

1. Class A--Detailed (Post budget--contract estimates). Estimate based on contract plans and evaluation of firm quotations for major material items.

2. Class B--Bid evaluation cost estimate (Post budget--contract estimates). Estimate based on contract plans and evaluation of contractor proposals in response to an RFP.

3. Class C--Budget quality estimate. Estimate based on an engineering analysis of detailed characteristics of item under consideration.

4. Class D--Feasibility estimate. Estimate based on technical feasibility studies and/or extrapolated from higher quality estimates of similar items.

For Element 1.0, the estimate for Alternative 1 was assigned Class A and the estimate for Alternative 2 was assigned Class B.

For Elements 2.0 and 3.0, the cost estimates for Alternatives 1 and 2 were determined to be Class C/Class D. That is, they were considered to be of budget quality or were based on extrapolations. For Alternative 1, this was based on lack of historical cost data for the new equipment currently being installed at the EW school. For Alternative 2, this was due to the fact that the EEMT program is currently in the system design and production phase.

Likewise, the estimates for Elements 4.0 and 5.0 were considered to be Class C/Class D. The new IPD curriculum for the ET school is in the process of being implemented and the new curriculum for the EW school is in the analysis phase so development cost data were limited and maintenance cost data were nonexistent. The curriculum development effort for EEMT device test and evaluation is in the early stages and no cost data were available.

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[7] Cost analysis (OPNAVINST 7000.17A). Washington, DC: Department of the Navy, September 1976.

CONCLUSIONS

The results of the comparative life-cycle cost analysis indicated that EEMT could be used in place of operational equipment in the teaching of 49.2 percent of the curricula at ET and EW "A" schools, and that the goal of a 50 percent cost reduction could be satisfied by implementing EEMT. It appears that this reduction can be made without sacrificing the level of training, since EEMT should provide equal or better training.

The reduced quantities of prime equipment planned for acquisition of the "A" schools will provide less hands-on laboratory training than is currently available. Even now laboratory training on prime equipment often allows only one active student with two or more observing.

One of the EEMT performance goals is maximization of individual hands-on laboratory training experiences in preventive maintenance tasks and corrective maintenance procedures. Both the EEMT system configuration and utilization plans are aimed at providing individual hands-on training.

The number of EEMT units projected for acquisition in the cost analysis was based on student throughput figures and assumed one student per station. Thus, it appears that a 50-percent life-cycle cost reduction over current training methods can be achieved with reduced reliance on operational equipment and increased hands-on training experience.

It should be noted that the analyses assumed a fixed level of training effectiveness for both alternatives. The performance goals and operational issues stated in the draft of the device test and evaluation plan for EEMT indicate that EEMT will provide both qualitative and quantitative improvements in training effectiveness.

Based on an analysis of training device support requirements[8] and the EEMT design and production procurement package, it appears that a fully deployable EEMT system with complete documentation and logistic support planning will be available at the end of the EEMT RDT&E program.

RECOMMENDATIONS

1. To provide historical cost data for program planning and budgeting, the costs of developing the EEMT instructional modules for device test and evaluation should be recorded as they accrue. Accumulation of these costs by development task and personnel type will permit realistic manpower planning and cost estimates for future curriculum development and maintenance efforts.

2. The LCCM should be updated during device test and evaluation to provide more reliable estimates of EEMT LCC to be used in determining whether or not the EEMT system should be put into full-scale production and deployed in other "A" schools.

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[8]The analysis of training device support requirements was prepared by Cog 2'0', the logistics support system for the Naval Training Equipment Center, Orlando.

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APPENDIX

COSTING METHODOLOGY

COSTING METHODOLOGY

This appendix provides details of the costing methodology used in this research. The two alternatives for comparative analysis are defined in operational terms, the parameters and assumptions used to derive the life-cycle cost (LCC) estimates are described, and the cost estimates developed for work breakdown structure (WBS) elements in the life-cycle cost model (LCCM) are provided.

The LCC analysis was performed to determine the potential for utilizing EEMT within the ET and EW "A" schools. Only those costs directly impacted by the introduction of EEMT into the training pipeline were considered; the cost of the total curriculum and equipment inventory for each school was not estimated.

Training Philosophies

The curricula at the ET and EW "A" schools reflect two different training philosophies. The ET school uses a representative-equipment approach, while the EW school uses an equipment-specific training approach.

ET "A" School

The representative-equipment approach is necessary at ET "A" school because of the diversity of communications and radar equipment that an ET may be required to operate and maintain. This philosophy calls for a large inventory of prime equipment, since it is assumed that the ETs will require a substantial amount of "hands-on" training if they are going to be able to extend their "representative" experience to the actual equipment they will be maintaining aboard ship. Unless there is widespread standardization of equipment in the fleet, the introduction of new prime equipment will not significantly change this training philosophy during the projected life cycle.

A new curriculum is currently being implemented in the ET "A" school. This curriculum was developed by merging the radar and communications tracks in the pipeline and by shifting common core fundamentals to modules 30 through 35 of the Basic Electricity and Electronics (BE/E) school. The new curriculum reduces the total number of student contact hours from 1140 to 840 and emphasizes "hands-on" training by allocating 454 hours (or 54%) to laboratory training and 386 hours (or 46%) to classroom instruction.

Table A-1 gives the hours devoted to classroom and laboratory in the new ET training pipeline. ET "A" school is divided into four units--digital fundamentals, advanced electronics, communications systems, and radar systems. After analyzing each unit, the topic areas listed in Table A-2 were identified as potential EEMT applications. These applications accounted for a total of 413 hours, or 49.2 percent of the 840 hours in the ET curriculum.

EW "A" School

The equipment-specific training approach used at EW "A" school is possible because of the limited number of types of EW equipment in use. The introduction of new equipment and phasing out of current equipment has not changed this training philosophy, but it is impacting the EW training pipeline by adding more sophisticated technology to the curriculum at the same time it is reducing the prime equipment inventory.

Table A-1

ET "A" School Classroom and Laboratory Hours

Unit		Classroom Hours	Laboratory Hours
1.0	Digital fundamentals	40	8
2.0	Advanced electronics	87	153
3.0	Communications systems	111	159
4.0	Radar systems	148	134

Table A-2

Potential EEMT Applications at ET "A" School, by Topic

Topic Number	Topic	Lab Hours	Classroom Hours	Possible EEMT Hours
Advanced Electronics				
2.1.1	Elements of Radio Communication	0.0	6.0	6.0
2.1.2	Communication Systems	0.0	6.0	0.0
2.2.1	Modulation Principles	12.0	6.0	15.0
2.3.1	Single Sideband TX Fundamentals	18.0	6.0	20.0
2.3.2	Single Sideband TX Circuits	39.0	32.0	36.0
2.3.3	Single Sideband RX Fundamentals	6.0	3.0	8.0
2.3.4	Single Sideband RX Circuits	21.0	10.0	17.0
2.4.1	TX Frequency Modulation Fundamentlas	9.0	3.0	8.5
2.4.2	FM Transmitter Circuits	10.0	2.0	6.0
2.4.3	RX Frequency Modulation Fundamentals	4.0	2.0	4.0
2.4.4	FM RX Circuits	16.0	6.0	13.5
2.5.1	Radio Frequency Transmission	7.0	4.0	9.0
2.5.2	Correct. Maint. Repair/Replacement	11.0	1.0	1.0
	Advanced Electronics Totals	153.0	87.0	144.0
Communications Systems				
3.1.1	AN/WRC-1	12.0	6.0	18.0
3.1.2	R-1051/URR	18.0	12.0	17.5
3.1.3	AN/URT-24	18.0	12.0	17.5
3.1.4	AN/URT-23 and AN/URA-38	39.0	21.0	40.5
3.2.1	AN/SRC-20/21 and AN/SRA-33	27.0	33.0	26.5
3.3.1	Intro. to Comm. Systems	0.0	3.0	0.5
3.3.2	HF FSK (RCS) System	14.0	8.0	3.5
3.3.3	UHF AFTS System	6.0	3.0	4.5
3.3.4	HF Multiplex (AFTS) System	13.0	7.5	0.5
3.3.5	CW System	6.0	2.5	6.5
3.3.6	Voice Operated Relay System	6.0	3.5	0.5
	Communications Systems Totals	159.0	111.5	132.5
Radar Systems				
4.1.1	Introduction to AN/SPS-10	6.5	19.5	26.0
4.1.2	Primary Power Distribution	8.0	9.5	8.0
4.1.3	AC Voltage Regulator	5.0	5.5	5.0
4.1.4	Modulator	9.0	13.5	8.0
4.2.1	Transmitter	6.5	14.5	5.5
4.2.2	RF System	2.0	1.5	2.0
4.2.3	DC Power Supply	6.5	7.5	6.5
4.2.4	Receiver	12.0	14.5	12.5
4.3.1	Adapter Indicator	8.5	5.0	7.5
4.3.2	Video Clutter Suppressor	0.5	2.5	0.5
4.3.3	Antenna System	10.5	12.5	8.5
4.4.1	Power Supplies/Timing	30.5	19.5	27.5
4.4.2	Sweep and DRA Sections	19.5	15.0	13.5
4.4.3	Brightening Section	11.5	7.5	7.5
	Radar Systems Totals	134.0	148.0	136.5

The new curriculum for the AN/SLQ-32 and associated equipment is currently being developed by the IPD detachment. Therefore, specific topic areas and time allocations were not available for a detailed analysis of potential EEMT applications. It was assumed that the overall length of the "A" school would remain 28 weeks (or 840 hours), but the emphasis would be changed to reflect the new equipment technology, increased practice in test equipment use, and the shift of some electronics fundamentals to BE/E. Personnel from both the EW school and the IPD detachment have indicated that the EEMT would be applicable in both the equipment operation and maintenance phases of the new curriculum. Therefore, the proportion of EEMT hours in the EW "A" school curriculum was assumed to be equivalent to the proportion of EEMT hours in the ET "A" school curriculum. A total of 413 EEMT hours, or 49.2 percent of the projected 840 hours in the new EW curriculum, was established.

Defining Alternatives 1 and 2

Given the figure of 49.2 percent for both schools, Alternative 1, the current practice of using operational equipment for training, was defined as:

1. The nonrecurring acquisition and logistic support costs associated with introducing new prime equipment and training devices into the "A" schools.

2. The recurring operation and maintenance costs associated with 49.2 percent of the equipment inventory over the projected 12-year life cycle.

3. The curriculum development costs associated with introducing new prime equipment into the training pipelines.

4. The recurring costs for maintaining 49.2 percent of the curriculum.

Alternative 2, the use of EEMT for electronics maintenance training, was defined as:

1. The nonrecurring acquisition and logistic support costs associated with implementing EEMT for 49.2 percent of the curriculum in each school.

2. The recurring operation and maintenance costs associated with EEMT over the projected 12-year life cycle.

3. The nonrecurring costs associated with development of EEMT instruction for 49.2 percent of the curriculum in each school.

4. The nonrecurring costs for maintaining EEMT instruction.

Operational Equipment Inventory for ET "A" School

The current inventory of operational equipment used at the ET school includes:

1. AN/SPS-10 radar sets (30 each).

2. AN/SPA-25 indicator groups (45 each).

3. AN/WRC-18 radio sets (26 each).

4. AN/R-1051 radio receivers (27 each).

5. AN/URT-23 radio transmitters (22 each).

6. AN/SRC-20/21 radio sets (28 each).

7. AN/SRA-33 antenna couplers (14 each).

The AN/SPS-10 radars in the fleet are scheduled to be replaced by AN/SPS-67 radars in the FY 82-88 timeframe. There are plans to reduce the number of AN/SPS-10 radar sets at the ET "A" school to six in FY 83 and to phase them out of ET training in FY 86. In estimating the costs for alternative one, it was assumed that the last six AN/SPS-10 radars would be replaced by six AN/SPS-67 radars, at a cost of approximately $140,000 each, in the FY 90-94 timeframe.

There are plans to replace all 28 of the AN/SRC-20/21 radio sets with 20 AN/WSC-3 line-of-sight radio sets, at a cost of approximately $40,000 each, in the FY 83 timeframe.

Operational Equipment Inventory for EW "A" School

The EW inventory (listed below) is currently being installed and no new acquisitions of operational equipment are planned during the projected life cycle. Since these acquisition and logistic support costs will be incurred prior to FY 83, they were considered sunk costs and were not included in the analysis.

1. AN/SLQ-32 (V2) (6 each).
2. AN/SLQ-32 (V3) (3 each).
3. AN/SLQ-32 (OTE) (2 each).
4. AN/WLR-8 (1 each).
5. AN/SLQ-17A (1 each).
6. AN/SLQ-34 (2 each).
7. AN/SSQ-82 (1 each).

Life Cycle Costs for Operational Equipment

Table A-3 gives the estimated LCCs for Alternative 1 for both schools.

ET "A" School

The cost estimate for ET "A" school training devices reflects replacement of the NIDA trainer inventory with equivalent devices. The NIDA trainers were introduced as part of the new ET "A" curriculum and it was assumed that replacement due to wear or obsolescence would be required after 7 years of service.

The logistic support costs in WBS Element 2.0 are associated with acquisition of both the AN/WSC-3 and the AN/SPS-67. The operational support costs in WBS Element 3.0 represent 49.2 percent of the estimated cost of operating and maintaining the ET equipment inventory over the projected 12-year life cycle. These estimates were based on requirements for maintenance support personnel and on the historical costs of spares, overhaul, and calibration of test equipment.

EW "A" School

The operational equipment in the EW "A" school's inventory will be used through the entire EW training pipeline, including "C" school laboratories, so "hands-on" laboratory training at the "A" school level will be limited. The existing AN/WLR-1 pipeline currently

Table A-3

Prime Equipment Training System Costs

Work Breakdown Structure (WBS) Elements and Subelements	ET "A" School	EW "A" School
1.0 <u>Training System Acquisition</u>		
01 Training equipment	$ 1,640,000	
02 Technical documentation	0	
03 Test equipment	0	
04 Training devices	240,000	$ 2,233,860
Acquisition Totals	1,880,000	2,233,860
2.0 <u>Traning System Logistic Support</u>		
01 Installation and Test	470,000	
02 Initial Spares/Maintenance Kit	275,000	
03 Tech Services/Tra Advisory Services	7,000	
04 Maintenance/instructor training	0	
05 Hardware modification	0	2,5000,000
06 Software updates/maintenance	0	2,5000,000
Logistic Total	752,000	5,000,000
3.0 <u>*Training System Operational Support*</u>		
01 Rep and Ret Services/Repl Services	2,710,751	2,952,000
02 Organizational maintenance	5,479,916	0
03 Overhaul	1,416,960	0
04 Calibration	481,880	1,948,000
Operational Total	10,089,507	8,343,000
Prime Equip Training Totals	$12,721,507	$ 15,576,860

<u>Legend</u>.

Rep = Repair

Repl = Replenishment

Ret = Return

Tech = Technical

Tra = Training

has 31 equipments and several major ECM/ESM trainers for use in both the "A" and "C" school laboratories. Therefore, it was assumed that major acquisition of several ECM/ESM trainers would be required to fill the gap in "A" school laboratories for the new pipeline. The estimate for training device acquisition in WBS Element 1.0 was based on AN/WLR-1 ECM/ESM trainer costs.

Since all of the equipment in the EW school's inventory are new, a number of engineering changes and modifications are anticipated during the initial years of the projected life cycle. For example, a surveillance capability may be required for the AN/SLQ-32. Based on discussions with EW school personnel, an estimate of $5,000,000 for hardware and software modifications was assumed for WBS Element 2.0.

The cost estimates for WBS Element 3.0 were based on current maintenance support personnel requirements and discussions with school personnel. Since the EW equipments are new and hence still under manufacturer support, no historical data on maintenance were available.

EEMT Life-cycle Costs

Table A-4 presents the EEMT training system costs distributed over the projected 12-year life cycle. As shown, the major cost is in WBS Element 1.0, acquisition of the EEMT units. Approximately 60 percent of the total EEMT life-cycle cost of $11,142,988 is incurred during the first 4 years of the life cycle for acquisition and nonrecurring logistic support.

Number of EEMT Units Required for ET "A" School

The following four-step computation was used to determine the numbers of EEMT 2D and 3D units required to support 49.2 percent of the curriculum for ET "A" school:

1. The projected average onboard (AOB) student population for FY 83 and beyond was determined to be 1,361.[1] This figure was multiplied by 413, the estimated number of EEMT hours in the ET curriculum, for a total of 562,093 EEMT student hours.

2. Even distribution of use was assumed, so this figure was divided by 140, the number of days in the course, to arrive at 4015 EEMT student hours per day. This figure was then divided by 16, the estimated hours per day of EEMT usage, to come up with an estimate of 252 units required to implement the EEMT curriculum within the "A" school.

3. It was assumed that all of the application areas identified for the advanced electronics portion of ET "A" school could be accomplished using the 2D unit. The ratio of 6:4 was established for the application areas identified for the communications and radar portions of ET "A" school. Therefore, a ratio of 37:13 for the 2D and 3D units was computed. This resulted in an estimated requirements of 186 2D units and 66 3D units to support the 413 hours of EEMT curriculum in the ET "A" school.

4. The fourth step considered class size, student-to-instructor ratios, instructor authoring and revision requirements, and downtime. The stated student-to-instructor

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[1] ET "A" school implementation brief. Great Lakes, IL: Naval Education and Training Program Development Center Detachment (NETPDCD), Naval Training Center, September 1979.

Table A-4

EEMT Training System Costs by Elements and Fiscal Years

WBS Elements and Subelements	FY83	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	Total
1.0 Acquisition													
01 Equipment costs	2,498,673	2,915,749	1,868,273										7,282,695
02 Technical doc.	--	--	--										--
Total hardware	2,498,673	2,915,749	1,868,273										7,282,695
2.0 Logistic Support													
01 Installation & test	4,615	4,615	4,615										13,845
02 Initial spares	74,141	74,141	47,874										196,156
03 Tools & test equip.	29,157	29,157	18,683										76,997
04 Tech/tra. adv. serv.	40,000	--	--										40,000
05 OP/maint. course	--	--	2,308		2,308		2,308		2,308		2,308		11,540
06 Hardware mods.	--	--	--	769,977	--		76,998		--		--	76,998	923,973
07 Software updates	--	--	--	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	270,000
Total logistic sup.	147,913	107,913	73,480	799,977	32,308	30,000	109,306	30,000	32,308	30,000	32,308	106,998	1,532,511
3.0 Operational Support													
01 R&R services				76,998	76,998	76,998	76,998	76,998	76,998	76,998	76,998	76,998	692,982
02 Org. maintenance													
Military	38,300	93,500	150,300	150,300	150,300	150,300	150,300	150,300	150,300	150,300	150,300	150,300	1,634,800
Contractor	--	--	--	--	--	--	--	--	--	--	--	--	--
Total oper. sup.	38,300	93,500	150,300	227,298	227,298	227,298	227,298	227,298	227,298	227,298	227,298	227,298	2,327,782
Total life cycle costs	2,684,886	3,117,162	2,092,053	1,027,275	259,606	257,298	336,604	257,298	259,606	257,298	159,606	334,296	11,142,988

Legend.
Adv = Advisory
FY = Fiscal year
Oper = Operational
Org = Organizational
Sup = Support
Tra = Training
WBS = Work breakdown structure

ratio is 22:1 for classroom instruction, 11:1 for laboratory training in Unit 2.0, and 6:1 for laboratory training in Units 3.0 and 4.0. Therefore, the number of 2D units was increased to 198 to provide several variations in classroom and laboratory configurations and a backup capability of approximately 6 percent over the number computed. The number of 3D units was increased to 69 to provide a full laboratory configuration for Units 3.0 and 4.0 and a backup capability of approximately 6 percent over the number computed. A total of nine instructor consoles was assumed for authoring and revision requirements.

Number of EEMT Units Required for EW "A" School

The same four-step procedure was used to determine the number of EEMT 2D and 3D units required to support 49.2 percent of the curriculum at EW "A" school.

1. Based on current and projected student throughput figures for the EW "A" school, the AOB student population for FY 83 and beyond was set at 450 students. This figure was multiplied by 413, the estimated number of EEMT hours in the EW curriculum, to obtain a total of 185,850 EEMT student hours.

2. Even distribution of use was assumed again, so the EEMT student hours were divided by the number of days in the course (140) and by the estimated hours per day of EEMT usage (16) to come up with a total of 83 units required to implement the EEMT curriculum within the "A" school.

3. The ratio of 2D to 3D units was established at 8:2 for the EW school, since the majority of potential EEMT applications will be 2D lessons specific to the AN/SLQ-32 and associated equipment. This resulted in a breakdown of 66 2D units and 17 3D units.

4. The stated student-to-instructor ratio is 16:1 for classroom instruction and 8:1 for laboratory training. Therefore, the number of 2D units was increased to 70 to provide 4 full classrooms of 8 laboratories or some combination of the two, and a 6 percent backup capability. The number of 3D units was increased to 18. A total of 9 instructor consoles was assumed for authoring and revision requirements.

Planned Acquisition of EEMT Units

For costing purposes, the number of production EEMT units to be acquired was reduced by the number of prototype units to be procured during the design and production phase of the program: 20 2D units, 2 3D units, and 2 instructor consoles. These units will be in place in the schools in FY 83 and represent sunk costs. Therefore, the prototype units were subtracted from the number of units needed to obtain production unit totals of 248 2D units, 85 3D units, and 16 instructor consoles. The total numbers of prototype and production EEMT units are given in Table 5.

EEMT Acquisition Costs

Based on the prices bid for optional units beyond the system design and development phase, the per unit production costs were set at $17,345 for the 2D unit, $35,088 for the 3D unit, and $1,000 for the instructor consoles. The cost estimate of $7,282,695 for WBS Element 1.0 (Table A-4) reflects acquisition of the production EEMT units listed in Table A-5.

Table A-5

Planned Acquisitions of EEMT Units

EEMT Unit Type School	Proto-types	Production Units FY 83	FY 84	FY 85	Totals	Prototype & Production Totals
2D Units						
ET "A" School	10	65	75	48	188	198
EW "A" School	10	16	26	18	60	70
	20	81	101	66	248	268
3D Units						
ET "A" School	1	25	26	17	68	69
EW "A" School	1	6	7	4	17	18
	2	31	33	21	85	87
Instructor Consoles						
ET "A" School	1	3	3	2	8	9
EW "A" School	1	3	3	2	8	9
	2	6	6	4	16	18

The philosophy underlying procurement of the EEMT prototype system is to provide a turnkey training system at the end of the program. Therefore, considerations for supportability and standardization under the Cog 2'0' (an inventory system for Navy training devices) requirements were included in the procurement specifications. The specifications call for the following technical documentation to be developed in conformance with applicable military standards:

1. Reliability program
2. Maintainability program
3. Quality assurance program
4. Configuration management program
5. Provisioning lists
6. Equipment manuals

Since initial acquisition costs for technical documentation were part of the EEMT prototype procurement package, these costs were considered sunk costs in the life-cycle analysis. Although revisions to the technical documentation may be required during the life cycle due to engineering changes, these costs were included in WBS Element 2.6, hardware modifications, and WBS Element 2.7, software maintenance/updates.

EEMT Logistics Support Costs

The cost estimates for logistic support of EEMT over the projected life cycle were based on reasonable projections of the costs of these items from other training programs. Contractor bids and/or historical cost data were not available. As shown in Table A-4, WBS Elements 2.1 through 2.4 are nonrecurring costs associated with the phased acquisition of EEMT. WBS Elements 2.5 through 2.7 are recurring costs over the 12-year life cycle. For WBS Element 2.1, installation and test, it was assumed that a contractor technician would be required for approximately 2 weeks for each installation. Since there are two schools with three installations each (one per year), a total of 12 man-weeks was estimated. Normally this type of support cost would be part of initial acquisition costs. However, it was not part of the per unit production costs used in WBS Element 1.1 so it was included here. Initial spares, WBS Element 2.2, were estimated at one maintenance kit per 20 units with each kit containing parts equal to approximately two-thirds the cost of a single unit. Special tools and test equipment were not considered necessary to support EEMT maintenance. However, to ensure adequate tools and test equipment, approximately 1 percent of the total unit costs were estimated for WBS Element 2.3. WBS Element 2.4, technical support and training advisory services, was estimated at one-third man-year of contractor effort at each school during the first year of the life cycle. This estimate also includes initial conduct of the instructor/maintenance training courses.

Since development of the instructor/maintenance training courses was part of the EEMT prototype procurement package, these costs were considered sunk and not included in the analysis.

WBS Element 2.5, instructor/maintenance training, was estimated at 2 man-weeks of contractor effort every 2 years over the life cycle to conduct and update the courses based on EEMT configuration changes. Hardware modifications, WBS Element 2.6, were assumed to occur every 3 years beginning in FY 86. The EEMT design philosophy emphasizes incorporating new developments in computer, display, and storage technologies into the system easily and cheaply without affecting software or other components. For example, videodisc is currently being studied as a replacement for microfiche in the 2D unit. Therefore, 20 percent of the acquisition costs was estimated for the initial modification in FY 86 and 10 percent was allowed for subsequent modifications during the life cycle. Software maintenance and updates, WBS Element 2.7, were estimated at one-half man year per year beginning in FY 86. Future software requirements will be driven by DoD efforts in the new programming language, ADA, that may eventually replace PASCAL, which is planned as the software basis for EEMT. Enrichment of author and student functions to enhance user support was also considered in the estimate.

EEMT Operational Support Costs

Contractor bids and/or historical cost data were not available to estimate the life-cycle costs for operational support. Reasonable projections for WBS Elements 3.1 and 3.2 were based on experience in other training programs and the EEMT technology configuration.

WBS Element 3.1, repair and return services and replenishment spares, was assumed to begin in FY 86 after acquisition of initial spares and support. Approximately 1 percent of the total acquisition costs were estimated as an annual cost. The EEMT design philosophy is to provide a turnkey system. Therefore, organizational maintenance level, WBS Element 3.2, is expected to be performed by military personnel. Based on current maintenance support requirements at the schools, it was assumed that personnel in the tradevman (TD) rating would provide EEMT maintenance support.

Curriculum Costs

The cost components within WBS Element 4.0 include the analysis, design, and development phases of the ISD procedures. However, for this cost comparison, only those costs associated with instructional materials development were considered. It was assumed that the level of effort required to perform the tasks within the analysis and design phases would be constant for both conventional instruction and EEMT lessons. Although the EEMT materials will require more prompts, cues, and feedback loops, these considerations are embedded in the development model used to derive the EEMT cost estimates.

The cost components within WBS Element 5.0 include implementation, control, and replacement training for instructor personnel. The costs associated with the implementation and control phases of the ISD procedures were combined into one cost estimate. In addition, a cost factor to cover instructor replacement training on EEMT authoring and revision procedures was included in the EEMT cost estimate for curriculum maintenance. The costs for conventional instructor replacement training were considered sunk costs that would be incurred whether or not EEMT was implemented.

Curriculum Development

Table A-6 summarizes the LCC estimates for curriculum development for both alternatives. Alternative 1 represents the costs associated with developing curriculum for new equipment to be introduced into the ET and EW training pipelines during the projected life cycle. Alternative 2 provides cost estimates for developing EEMT instruction for 49.2 percent of the curriculum in each school.

Table A-6

Curriculum Development Costs and Hours

School	Operational Equip. (Alternative 1)		EEMT (Alternative 2)	
	Dollars	Hours	Dollars	Hours
ET "A" School	$55,981	3,675	$226,322	15,276
EW "A" School	35,509	2,450	251,700	17,366
Totals	91,490	6,125	478,022	32,642

The estimated cost for developing EEMT instruction was $478,022. This is significantly higher than the estimated cost of $91,490 for Alternative 1, since most of the costs associated with implementation of new curriculums in the ET and EW schools were considered sunk costs incurred prior to FY 83. Although it is reasonable to assume that new electronic technologies, new equipments not currently projected for acquisition, or major changes in training philosophy could require development of completely new

curriculums during the projected life cycle, these potential development costs were not considered. If EEMT is an integral part of the training pipeline, separation of these development costs will be irrelevant.

The following paragraphs provide the assumptions and computations used to derive the curriculum development cost estimates for each alternative.

Conventional Training Development Model. The estimate for the ET school represents costs associated with developing curriculum for the AN/WSC-3 line-of-sight radio set and the AN/SPS-67 radar set. It was assumed that the number of hours of instruction for these new equipments would approximate the hours scheduled for the existing equipment. Therefore, a total of 150 hours, 60 for the AN/WSC-3 and 90 for the AN/SPS-67, was assumed for curriculum development during the projected life cycle.

Based on personnel cost data in the ET "A" Implementation Brief (see note 1) and on manpower planning data in the Preliminary Plan of Action and Milestones[2] (POA&M), the development cost per hour of instruction was computed and then broken down into military and civilian costs to arrive at the number of man-hours required by personnel type per hour of instruction. The total cumulative cost of $313,647.18 stated in the ET "A" Implementation Brief (see note 1) was divided by 840, the number of hours of instruction, for an average of $373.39 per hour of instruction with a breakdown of 90 percent civilian time and 10 percent military time. Based on annual billet costs by rating and pay grade (Koehler, 1980) the military personnel costs per hour were calculated as $13.73 for the ET rating, assuming an E-7 pay grade. The civilian personnel costs per hour were taken at $15.40, assuming the FY 80 cost for a GS-9, Step 5, with 11 percent labor costs and 55 percent support overhead. Using these personnel costs, a figure of 24.5 man-hours per hour of instruction was computed. Based on the above figures and the following computation, the curriculum development costs for the 150 hours of new instruction for the ET "A" school were calculated at $55,981.

The estimate for the EW school reflects costs associated with developing a portion of the AN/SLQ-32 curriculum. Although the new curriculum should be implemented by FY 83, additional development effort for the new equipment curriculum was considered likely during the initial years of the projected life cycle. Therefore, 100 hours of the total 840 hours were assumed for EW curriculum development.

The figure of 24.5 man-hours per hour of instruction derived for the ET school, with a breakdown of 65 percent civilian effort and 35 percent military effort for the EW school, was used to compute development costs. Based on annual billet costs by rating and pay grade (Koehler, 1980), the military personnel costs per hour were calculated at $12.81 for the EW rating, assuming an E-7 pay grade. The civilian personnel costs per hour were held constant at $15.40. Using the same computation, the curriculum development costs for the EW "A" school were calculated at $35,509.

EEMT Development Model. The personnel required to develop EEMT instructional materials are subject matter experts (SMEs), instructional developers, data entry operators, and photographers. The elements in the EEMT instructional development process can be broken down into five areas: (1) material development, (2) data base entry, (3) photography, (4) data base checkout, and (5) data revision.

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[2] Preliminary Plan of Action and Milestones. Unpublished Navy document.

The data gathered during the analysis and design phase of the ISD procedures are used to develop the EEMT data base and supporting materials, as well as identify the image requirements. The number of images required determines the instructional development time. Six steps are required to determine the man-hours to develop EEMT lessons:

1. Develop a normal-procedures matrix.

2. Develop an abnormal-procedures matrix.

3. Total all the conditions that might occur.

4. Eliminate any condition not needed for instruction.

5. Determine the total number of instructional images.

6. Determine the man-hours or the course length.

The process of determining the man-hours (Step 6) required to develop EEMT instructional materials was based on EEMT experience to date. An average of 40 images is required to support 1 hour of instruction with a factor of 1.34 man-hours per image for instructional materials development. Therefore, an average of 53.6 man-hours per hour of EEMT instruction was computed for use in the comparative analysis. The proportion of personnel time required to develop instruction to support 40 images is as follows: SME--35 percent, instructional developer--52.5 percent, data entry operator--8 percent, and photographer--4.5 percent. Based on this, the military personnel costs per hour for each school remained the same as calculated for Alternative 1 and the level of effort was set at 35 percent. The civilian personnel cost per hour was held at $15.40 and the level of effort was set at 65 percent.

Although a total of 413 hours or 49.2 percent of the curriculum for each school was identified for potential EEMT application, approximately 200 hours of EEMT instruction will be developed for the operational test and evaluation to be conducted in the next phase of the program. The costs for developing this testbed instruction were considered sunk costs and subtracted from the costs for developing 413 hours of instruction for each school. The EEMT testbed instruction will consist of 103.5 hours of generic instruction for families of equipments and 94 hours of instruction on representative equipment. The generic instruction is broken down into 33.5 hours for communications systems, 25 hours for radar systems, 25.5 hours for ECM/ESM systems, and 19.5 hours (or 18 percent) for common core instruction. The representative equipment instruction is broken down into 20 hours for the AN/SPS-10, 30 hours for the AN/WSC-3, and 44 hours for the AN/SLQ-32. Adding these hours, including common core, reduces the figure of 413 hours for each school to 285 hours for the ET school and 324 hours for the EW school.

The computations resulted in an estimate of 15,276 man-hours for a cost of $226,322 for ET school and an estimate of 17,366 man-hours for a cost of $251,700 for EW "A" school.

Curriculum Maintenance

The components for WBS Element 5.0 include personnel costs to update and revise instructional materials, recurring costs for reproduction and consumables, and recurring costs for replacement training for the instructional staff. Curriculum revisions are the result of changes in operational procedures, equipment engineering changes, or summative

evaluation of instructional materials. As shown in Table A-7, the life-cyle costs for curriculum maintenance for Alternative 1 were estimated at $3,353,568, approximately $1,200,000 more than the estimates for Alternative 2. Since EEMT is a computer-based generic training system, the personnel effort required to revise and update the curriculum is minimized. Only minor changes in existing data bases are required unless new equipments that are functionally and technologically different are introduced. EEMT has the advantages of common core instruction and reduced requirements for consumables and for reproduction of training materials, as well as ease of revision.

Table A-7

Curriculum Maintenance Costs

School	Operational Equip (Alternative 1)	EEMT (Alternative 2)
ET "A" School		
Personnel	$ 969,446	$ 551,373
Materials	1,080,000	675,000
Replacement Training	0	27,460
ET Totals	2,049,446	1,253,833
EW "A" School		
Personnel	704,122	533,959
Materials	600,000	325,000
Replacement Training	0	10,248
EW Totals	1,304,122	919,207
Program Totals	$3,353,568	$2,173,040

Based on POA&M data, a two-person level of effort (one civilian and one military SME) was assumed at each school for maintenance of the operational equipment. The hourly pay rates established for curriculum development cost estimates were multiplied by 2080 man-hours per year and then by 12 years for the projected life cycle. An additional sum of $50,000 per year for the EW, and $90,000 per year for the ET school, was added to cover the costs of consumables and reproduction materials.

A two-person level of effort, one civilian and one military SME, was assumed at each school for EEMT curriculum maintenance. The hourly pay rates established for the curriculum development cost estimates were multiplied by 2080 man-hours per year and then by 10 years. It was assumed that the first 2 years of the 12-year life cycle would be spent developing the EEMT curriculum for each school.

Common core instruction was 18 percent of the total EEMT testbed instruction for the two schools.

Assuming the same commonality, this common core instruction will not have to be maintained totally by both schools. Therefore, the cost savings were distributed equally

for each school over the 10-year curriculum maintenance period by applying a reduction factor of 9 percent.

Based on the amount of on-line data available to the student using EEMT, it was assumed that at least a 25 percent reduction in the costs of consumables and reproduction over the 10-year maintenance period would be realized. Computation of costs for replacement training for instructors was based on the projected AOB student population, the stated student-to-instructor ratio, and the assumption that approximately one-third of the instructors (i.e., 25 for the ET school and 10 for the EW school) would require an 8-hour EEMT training session annually during the 10-year maintenance period. The hourly payrates established for military personnel were used to derive the estimates.

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